

Space Research and the Problem of the Origin of Life

Part A of the following report was presented by Horowitz as background material at the Stanford conference on extra-terrestrial biology, February 21, 1959. Part B is a summary of comments on the biological importance of space exploration. Present at the conference were: Calvin, Davies, Hibbs, Horowitz, Kamphoefer, Krauskopf, Lederberg, Marr, Mazia, van Niel, Novick, Stanier, Stent, Weaver.

A. History of the Origin of Life Problem

From classic Greek times until the late 19th century, it was generally accepted that living matter in one form or another could originate spontaneously from non-living material. The frequently observed presence of insects, worms, frogs, etc. in mud or decaying organic matter was considered proof that these animals were generated spontaneously, without parents. This notion was disproved by Redi in 1668, but it was revived almost immediately following the discovery of microorganisms by Leeuwenhoek in 1675. Disproof in the case of microorganisms was difficult for technical reasons. Besides, people clung to it because bacteria, so small and apparently simple, seemed to be in the twilight zone between living and non-living matter. (Actually, these organisms are as complex as any cell of our own bodies.) Spontaneous generation of microorganisms was finally disproved by Pasteur in 1862.

Pasteur's experiments produced a reaction. Many scientists, especially physical scientists, came to the conclusion that these experiments demonstrated the futility of inquiring into the origin of life. They proposed that life had no origin, but, like matter, was eternal. This was the view of Arrhenius, Helmholtz, and Lord Kelvin. Arrhenius, especially, elaborated this idea which he called the theory of panspermia. He proposed that life-bearing seeds are scattered through space, and that

they fall on the planets and germinate wherever conditions are favorable. In addition to this, Arrhenius suggested a mechanism by which spores with diameters of the order of 0.1 micron could be carried beyond the gravitational field of the planet of their origin and be propelled (by light-pressure) through space to other planets. Arrhenius concluded from this theory that living things throughout the universe are related and should consist of cells composed of carbon, hydrogen, oxygen, and nitrogen.

The panspermia theory is much less attractive today than it was fifty years ago. Life is now regarded as a manifestation of certain molecular combinations. Since these combinations are not eternal--indeed, neither the elements nor matter itself are eternal, according to modern cosmologists--it is impossible to accept the idea that life has always existed. In addition, the escape of spores from the gravitational field of the earth and their survival in the unfiltered radiation of outer space seem much more difficult problems to us than they did to Arrhenius.

With increasing knowledge of the chemical nature of living matter has come a renaissance of the idea of spontaneous generation, this time at the molecular level. In the 'twenties, Oparin and, independently, Haldane, proposed that the origin of life was preceded by a long evolution of organic compounds of ever-increasing complexity on the earth's surface. In the pre-biotic, sterile world, these compounds could accumulate in the seas and eventually, by random combinations, produce a living molecule or molecular combination. (Differences of opinion as to the nature of the first living thing are ignored here.) Oparin pointed out that the synthesis of organic compounds requires reducing conditions, since these compounds are unstable in the presence of oxygen. He proposed an atmosphere of methane,

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ammonia, water, and hydrogen for the primitive earth. Urey later showed that methane, water, and ammonia are the stable forms of C, O, and N in the presence of excess hydrogen. Since hydrogen is the predominant element of the cosmos, it is reasonable to assume that it was present in large amounts on the primitive earth. Urey suggested that ultraviolet light could provide the energy for organic synthesis in the primitive atmosphere. Model experiments by Miller have shown that organic compounds including amino acids, organic acids, and urea are in fact produced when ultraviolet or an electric discharge is passed through such an atmosphere.

Finally, modern genetics and evolutionary theory show that it is possible, starting with a single living particle in an environment rich in organic compounds, to account for the evolution of all living species.

B. The Significance of Space Research for Biology

The discovery of life on another planet would be one of the momentous events of human history. Such a discovery would do more than answer a universal curiosity, however; it would also be of enormous scientific interest. Next to the synthesis of living matter in the laboratory, it would be the most important step that could be made toward an understanding of the problem of the origin of life. Among the fundamental questions which it might solve is the question of the uniqueness of systems based on nucleic acid are found on another planet, what will it be possible to say about the question of independent origin versus common origin by a mechanism of the Arrhenius type? Although it is unlikely that large numbers of spores could escape from the gravitational field of the earth by the electrostatic mechanism proposed by Arrhenius, the possibility of escape of an occasional spore cannot be excluded.

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Important information which would bear on this question can be obtained now, in the neighborhood of the earth. For one thing, it would be desirable to learn more about the vertical distribution of microorganisms in the atmosphere. For another, more information about the ultraviolet flux in space is essential for estimating the chances of survival of spores.

Another basic biological problem that should be considered in advance is that of recognizing living material that is not chemically similar to our own. Such organisms may have metabolic rates and growth rates much lower than anything we are familiar with.

Although the possibility of detecting and studying life on other planets is the most exciting aspect of space exploration, the biological importance of space research is not limited to the study of extra-terrestrial life. Even if no life is found on them, the possibility of sampling the organic compounds on other worlds can yield invaluable evidence bearing on the origin of life. These sterile worlds may well provide unique clues to the organic chemical processes which preceded the development of life on the earth. The recent observations of Sinton on Mars and of Kozyrev on the moon make it appear likely that large scale chemical processes involving carbon are taking place on these bodies. Although it is virtually certain that life occurs elsewhere in the universe, the a priori likelihood of its being found on other bodies of our solar system, especially the moon, is not high; consequently, the importance for biology of geochemical research of the type mentioned should not be minimized.

In brief, there is reason to think that the results of space exploration will be of biological interest regardless of whether extra-terrestrial life is actually found. For this reason, it is all the more important to minimize

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contamination, either chemical or biological, of the moon and planets. It should be possible to set up tolerance limits for contaminants and rules of procedure which will safeguard the possibilities for significant biological investigations in space without impeding the development of other programs.